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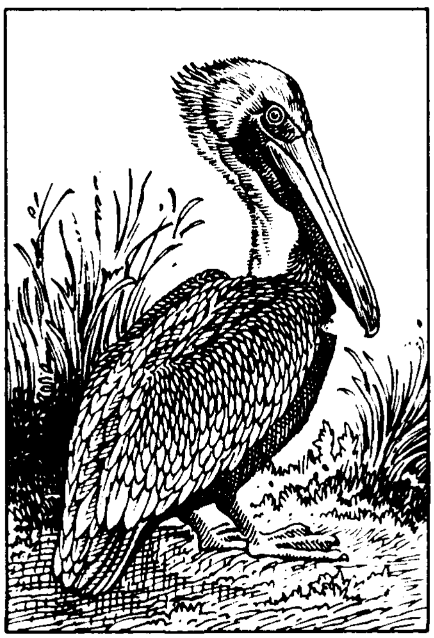
Habitat Value of Man-Made Coastal Marshes in Florida

by Thomas H. Roberts



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Twenty-two man-made coastal marshes of various ages were studied to determine their similarity to natural marshes. The majority of the sites were dominated *Spartina alterniflora*. Sites were located throughout northern and central Florida and ranged in age from approximately 1 to 10 years. The focus of the study was on the fish and wildlife habitat value provided by created wetlands. Vegetation characteristics were highly variable, but sites that were properly planned, constructed, and maintained served as viable habitat for animals normally associated with coastal marsh systems. Factors influencing site use by various animal groups and suggestions for future mitigation efforts are discussed.

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Preface

This study was sponsored by the Regulatory Branch, Jacksonville District, US Army Corps of Engineers (USACE). The report was prepared by Dr. Thomas H. Roberts of the Resource Analysis Group (RAG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). During a portion of the study, Dr. Roberts was a member of the Wetlands and Terrestrial Habitat Group (WTHG). Mr. Chester O. Martin was Team Leader, Wildlife Resources Team.

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While the work was performed Dr. Hanley K. Smith was Chief, WTHG. The report was prepared under the general supervision of Mr. E. Carl Brown, Chief, WTHG, Mr. H. Roger Hamilton, Chief, RAG; Dr. Conrad J. Kirby, Chief, Environmental Resources Division (ERD); and Dr. John Harrison, Chief, EL. Technical review was provided by Mr. Michael L. Davis, Regulatory Branch, USACE, Dr. Mark LaSalle, Coastal Ecology Group, ERD; Mr. Chester O. Martin, RAG; Dr. Wilma A. Mitchell, RAG; and Dr. James S. Wakeley, WTHG, ERD. The report was edited by Ms. Janean Shirley of the WES Information Technology Laboratory.

Wetlands were located with assistance from personnel from the following agencies: USACE, Florida Department of Environmental Regulation, Florida Department of Natural Resources, US Environmental Protection Agency, Florida Game and Freshwater Fish Commission, National Marine Fisheries Service, and US Fish and Wildlife Service. Two private firms, Ecoshores, Inc. and Mangrove Systems, Inc., provided information on coastal wetlands that they constructed. The following persons provided valuable assistance with study design, site selection, fieldwork, or data analysis and interpretation, and their contributions are gratefully acknowledged: Mr. Joseph R. Bacheler, Ms. Sharinda Bohall, Ms. Marie G. Burns, Mr. Curtis Kruer, Ms. Dianne Rosensweig, Mr. Chuck Schnepel, and Mr. Michael S. Zimmerman, Jacksonville District, USACE;

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1 Introduction

Background

Mitigation in the form of habitat creation or restoration is often employed to minimize the losses of wetlands and wetland resources resulting from development and other human activity. Most projects in coastal areas of northern and central Florida have involved the creation of wetlands dominated by smooth cordgrass (*Spartina alterniflora*) and black needlerush (*Juncus roemerianus*) [hereafter referred to simply as *Spartina* and *Juncus*].

Procedures for creating salt marshes were developed as a means to stabilize dredged material (Woodhouse, Seneca, and Broome 1974) and eroding shorelines (Woodhouse, Seneca, and Broome 1976). The first projects were completed in the early 1970's, but only during the past 5 to 7 years have man-made wetlands been extensively used to mitigate for losses of natural wetlands. Although wetland creation is a relatively new technology, it has been clearly demonstrated that many types of wetland vegetation can be established on areas that were formerly uplands. Edwards and Woodhouse (1982), Lewis (1982), Newling and Landin (1985), and Dial and Deis (1986) all found that *Spartina* can be successfully established in suitable areas when proper site preparation and planting techniques are used.

Despite technological developments in wetland creation, there are still questions as to whether man-made wetlands are "ecologically equivalent" to naturally occurring wetlands. One area of special interest involves the quality of man-made wetlands as habitat for fish and wildlife. Use of man-made coastal marshes in Florida by a variety of species has been reported (Dial and Deis 1986); however, an extensive, statewide survey that examined the relationships between site factors and animal use had never been undertaken.

Objectives

This study was conducted to determine the effectiveness of marsh creation as mitigation for losses of coastal wetlands in northern and central Florida. The emphasis was on the fish and wildlife habitat value of man-made marshes although data on a variety of other parameters, e.g., soil, vegetation, and below-ground plant biomass, were also gathered.

Study Sites

Study sites were selected during summer 1986 and spring 1987. Of 38 man-made marshes visited, 21 *Spartina* marshes and one *Juncus* marsh were selected for study. An attempt was made to locate an equal number of wetlands in five age classes; however, this was not possible and only two sites over 5 years old were studied. Each marsh was assigned to one of four age classes: less than 1.5 years, 1.5 to 3 years, 3 to 5 years, and greater than 5 years. On the Gulf Coast, sites were located from Pensacola to Tampa and on the Atlantic coast from Jacksonville to Vero Beach (Figure 1). In addition to the man-made wetlands, six natural marshes

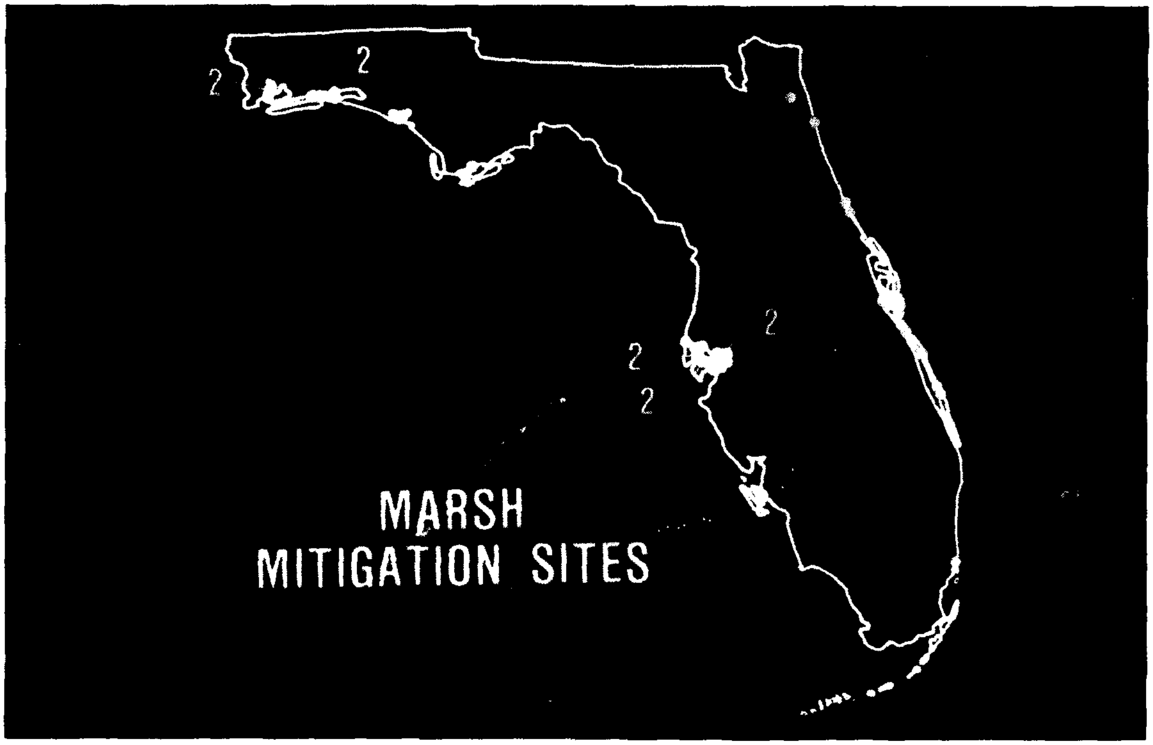

Figure 1. Location of study sites

were also sampled. They served as the basis for comparisons and provided a measure of the range of values and normal variability found in coastal marshes. Natural marshes that approximated the size of the man-made wetlands could not be found, so portions of extensive coastal marshes were used. Distinct features like tidal creeks served as boundaries of the sections studied. Four of the natural marshes were dominated by *Spartina* and two by *Juncus*. This report deals with *Spartina*-dominated marshes but data from the *Juncus* marshes are included in the tables for comparison. Table 1 lists site locations, size, and age at the time vegetation was sampled.

Table 1
Age, Size, and Location of Man-Made and Natural Marshes

Site Name	Age, yr	Size, ha	Location
Man-Made Marshes			
Bouchelle Island	1.4	0.28	Port Orange
Canaveral Bay	1.2	0.01	Cocoa Beach
Harbor Isles	1.0	0.12	Cocoa Beach
Mariner's Square	1.2	0.04	Cocoa Beach
MacDill AFB	1.2	2.8	Tampa
Thunder Bay	1.2	0.61	St. Petersburg
Feather Sound A	2.3	0.53	St. Petersburg
Harbour Island	2.3	0.36	Tampa
Ramada Hotel	1.8	0.28	Tampa
Destin Yacht Club	2.2	0.02	Destin
Sea Grove West	2.1	0.45	Vero Beach
St. John's Landing	2.5	0.20	Jacksonville
Williamson's Home	2.8	0.04	Daytona Beach
Costa del Sol	4.0	0.04	Cocoa Beach
Feather Sound B	3.3	0.61	St. Petersburg
Fountain Cove	4.3	0.04	Cocoa Beach
Gandy Bridge	4.4	0.004	Tampa
Placido Bayou	4.2	0.49	St. Petersburg
Porpoise Point	4.7	0.49	St. Augustine
Tiger Point[1]	5.2	0.89	Gulf Breeze

[1] *Juncus roemerianus* marsh.

Continued

Table 1 (Concluded)			
Site Name	**Age, yr**	**Size, ha**	**Location**
Man-Made Marshes (Continued)			
Bay Shore Parkway	10.0	0.28	Pensacola
Gardinier	9.4	2.50	Tampa
Natural Marshes			
Bay Point Natural[1]	--	0.45	Panama City
Gardinier Natural	--	0.69	Tampa
Philippi Park	--	0.20	Tampa
Power Plant	--	0.36	Port Orange
School for the Deaf	--	0.69	St. Augustine
Tiger Point Natural[1]	--	3.2	Gulf Breeze

[1] *Juncus roemerianus* marsh.

All but one of the marshes evaluated in this study were created by grading upland areas to an elevation that would receive regular tidal inundation and would support native wetland plants. The other marsh, Porpoise Point, was a combined creation and restoration project. There, an existing marsh was enlarged by planting *Spartina* along with some high marsh species. Only those projects where vegetation had been successfully established were sampled. Those that had failed because of poor site preparation, wave erosion, etc., were not suitable for addressing the objectives of the study. However, records were kept on all sites in order to evaluate causes of failure and to estimate the percentage of marsh construction projects that are successful.

2 Methods

Three man-made marshes and one natural marsh were sampled during October and November 1986 as part of a pilot study to test field procedures. These were Feather Sound A, Feather Sound B, Ramada Hotel, and Phillippi Park. The remainder of the sites were sampled during 1987. Birds were surveyed during April and May and again in September and October; mammals during April and May; and soil, vegetation, biomass, and fish during September and October. Fish sampling was conducted by personnel from the National Marine Fisheries Service's Beaufort Laboratory. The remainder of the data were collected by personnel from the US Army Engineer Waterways Experiment Station.

Soils

Soil samples were collected at random locations throughout the study sites. The number of samples varied according to the size of the site but generally, three to five were taken. Particle size distribution (texture) and percent organic matter were determined by laboratory analysis of composited samples. Munsell color was recorded for a sample judged to be typical of the site.

Vegetation

Measurements included: percent cover (total and by species), stem density, and height. Vegetation was sampled along stratified random transects using a modification of the point-intercept method (Mueller-Dumbois and Ellenberg 1974). At each sampling point, a slender rod was dropped five times at evenly spaced intervals. Hits or misses were recorded for each drop. This procedure was repeated at 2-m intervals. Between 100 and 200 drops were made on all but very small sites. Percent cover was calculated by the number of "hits" on a species divided by the total number of points sampled (drops). Stem counts of *Spartina* and *Juncus* were made

in 0.25-m^2 quadrats randomly located along each transect line. Height of the vegetation was recorded at each of the 2-m intervals.

Below-ground Biomass

Five samples were collected from each marsh to examine below-ground biomass development. Cores (7 cm by 18 cm) were extracted with a soil auger, washed in the field to remove as much extraneous material as possible, and preserved in plastic bags. All cores were taken directly over a culm of *Spartina* that had been clipped at ground level. Samples were further cleaned in the laboratory by washing them over very fine mesh sieves to prevent the loss of small roots; they were then placed in a drying oven set at 102° C. Samples were weighed several times over a period of 4 to 7 days until weights stabilized. The residual weight represented the dry weight of below-ground biomass.

Surface Macroinvertebrates

The large macroinvertebrates living on the marsh surface were tallied inside two 0.25-m^2 quadrats randomly placed along each vegetation transect. The marsh periwinkle (*Littorina* spp.), which climbs vegetation to stay above the rising tide, was counted both aboveground and on the surface.

Fish

Fish were collected in fyke nets (generally two per site) set at the edge of the marsh (Figure 2). Nets were put into place after the marshes were inundated by the rising tide and were run as the tide was ebbing to collect fish that had moved onto the marshes. Samples were preserved in 10-percent Formalin for later identification. Breder traps (Breder 1960; Sargent and Carlson 1987) were used to collect supplemental samples of small forage fish and juveniles of larger species. A Wegener Ring (Wegener, Holcomb, and Williams 1973) was used to sample tidal creeks on some sites.

Birds

Each marsh was thoroughly searched on three consecutive days and all individuals seen or identified by calls were recorded. Taped calls were used to elicit responses from species such as the clapper rail (*Rallus*

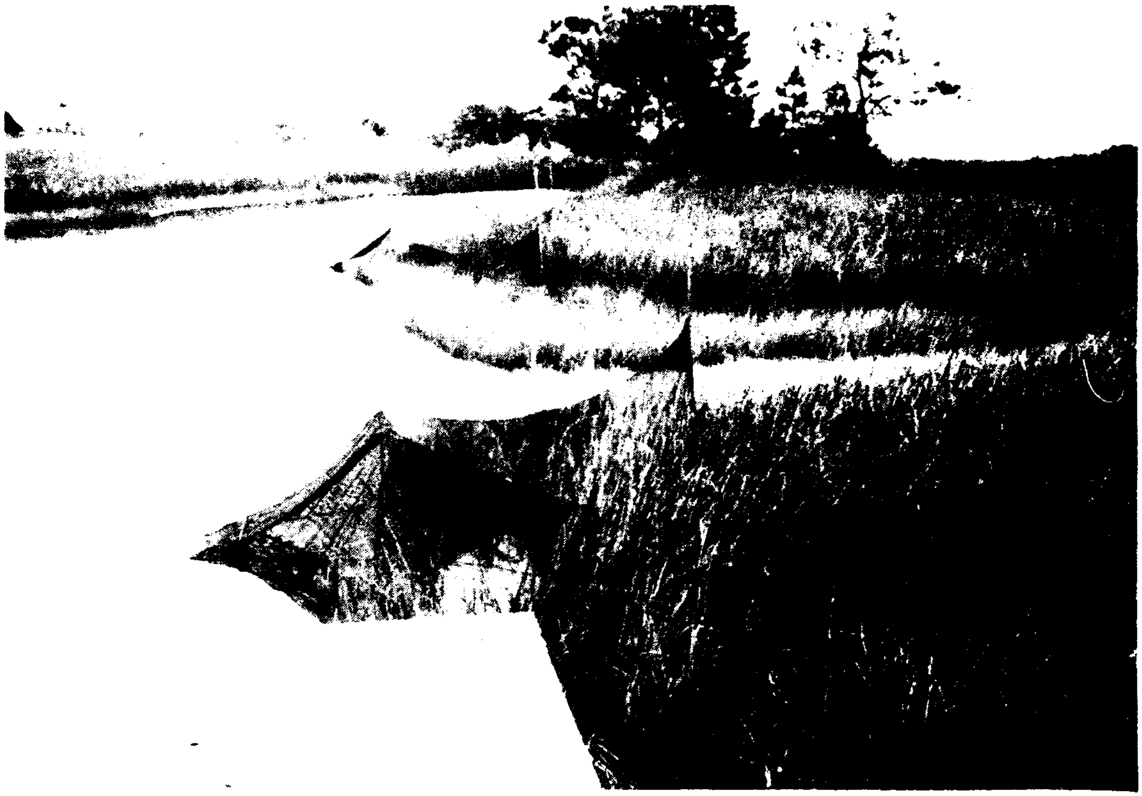

Figure 2. Fyke nets used to collect fish

longirostris) and marsh wren (*Cistothorus palustris*), which are secretive and difficult to flush. An attempt was made to count all individuals on each site. The presence of nests or young birds was noted.

Mammals

Small mammal presence was determined by trapping each site for two consecutive nights. Traps fastened to floating platforms were placed in all major vegetation zones. Two traps, one Sherman box trap and one Museum Special snap trap, were used on each platform (Figure 3) to enhance the chances of captures, as some species are somewhat trap selective. The use of two traps also allowed multiple captures. The number of traps varied according to the size of the area, but typically there were from five to seven stations per site (20 to 24 trap-nights). Bait was a mixture of peanut butter, oats, and sardines. Live-trapped animals were marked so recaptures could be recognized. All animals were identified to species. Use of the sites by larger mammals such as raccoons (*Procyon lotor*) was determined by systematically searching the areas for tracks, droppings, and other identifiable signs.

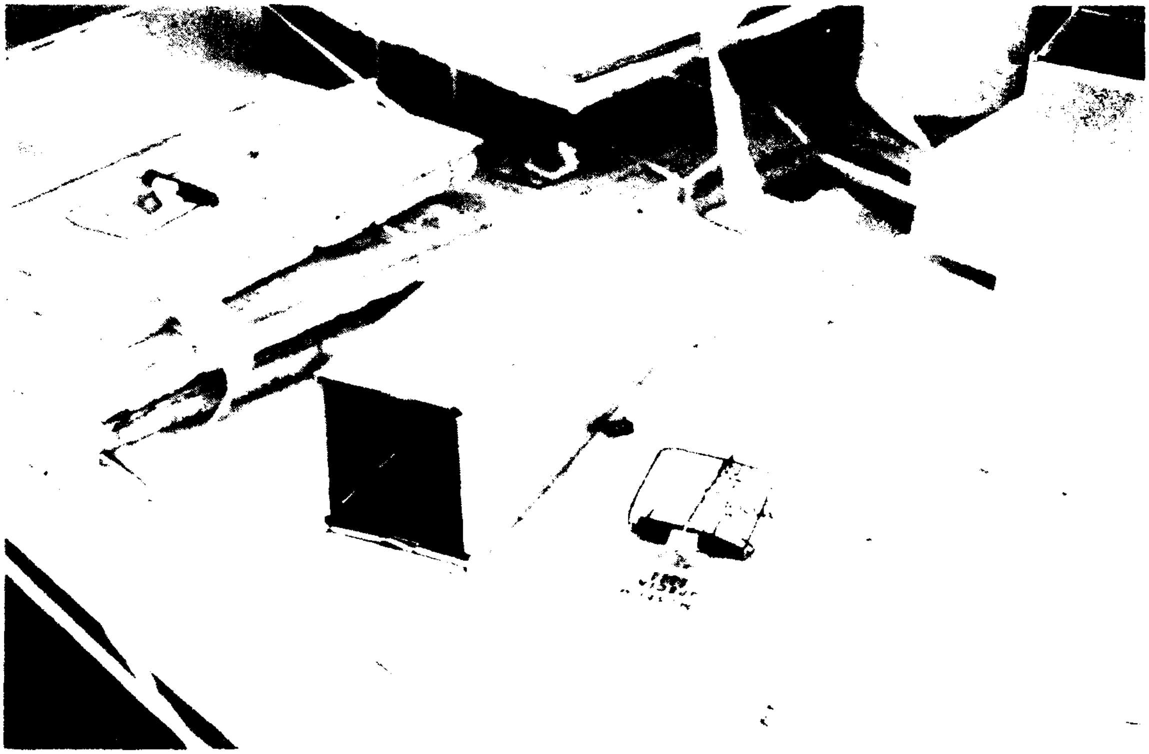

Figure 3. Placement of small mammal traps on floating platforms

Data Analysis

Linear regression was used to analyze trends in development of marsh vegetation. Student's "t" test was used to determine if characteristics of man-made marshes (by age class) differed from that on the natural areas. Analysis of variance was used to test for differences among age classes. All analyses were conducted using SAS (SAS Institute 1985). Statistical significance was accepted at the 0.10 level.

Because intensity of sampling for fish varied among sites, statistical comparisons with the natural marshes (and among the various ages of man-made marshes) could not be made. Czekanowski's coefficient of similarity (C_s) (Southwood 1978) was used to compare fish populations of man-made marshes to those of natural marshes. The index ranges from 0 (no species in common) to 1 (all species in common).

3 Results and Discussion

Soils

Soils from all natural marshes and all but one man-made marsh were classified as sand, sandy loam, or loamy sand (Table 2). Only one marsh, Mariner's Square, was composed of enough fine-textured material to be classified as a loam. Most of the Munsell color designations indicated that organic matter was present in the soil (the original sand would have had both a high value and chroma, e.g., 7/3 or 8/4). Overall color values for man-made marshes were lighter than those of natural marshes.

Average organic matter content ranged from 0.2 to 14.4 percent and varied widely within age classes (Table 2). For example, in the less than 1.5-year-old age class, the average organic matter content ranged from 0.6 to 10.1 percent. The natural marshes similarly exhibited a great deal of variability. Regression analysis indicated that organic matter had not increased with age ($r^2 = 0.04$). This finding is likely due to inadequate time for development (a few years instead of decades or centuries) and to the high variability associated with a relatively small sample size.

Vegetation

The man-made marshes ranged in age from 1 to 10 years and in size from approximately 0.004 to 2.8 ha (mean = 0.49 ha, SD = 0.75 ha). Most were fully covered by *Spartina* and many could not be distinguished visually from naturally occurring marshes. However, there was considerable variability among the man-made marshes, and between them and natural marshes. *Spartina* cover ranged from 40.0 percent on a 2-year-old site to nearly 80.0 percent on a site only 1 year old. The average cover of *Spartina* over all the man-made marshes was 59.7 percent (SD = 10.8). Many marshes were quite diverse with zones dominated by species such as *Distichlis spicata*, *Paspalum distichum*, or *Batis maritima*, so the total cover of the marshes was generally higher (mean = 70.2, SD = 13.9) than that of *Spartina* alone. Total cover ranged from 43.7 percent to 100 percent. On some man-made marshes, *Spartina* was robust with heights approaching

Table 2
Soil Characteristics of Marshes

Site	Munsell Value/Chroma	Texture	Organic Matter (%)
< 1.5 Years Old			
Bouchelle Island	4/1	loamy sand	2.3
Canaveral Bay	5/2	sand	1.0
Harbor Isles	2/0	sandy loam	1.3
Mariner's Square	6/1	loam	10.1
MacDill AFB	3/1	sand	2.9
Thunder Bay	4/2	sand	0.6
1.5 - 3 Years Old			
Destin Yacht Club	6/2	sand	0.2
Feather Sound A	2/1	sand	2.3
Harbour Island	5/2	sandy loam	1.3
Ramada Hotel	5/1	sand	4.0
Sea Grove West	7/1	loamy sand	1.4
St. John's Landing	2.5/1	sand	0.9
Williamson's Residence	4/1	loamy sand	2.1
3 - 5 Years Old			
Costa del Sol	2.5/1	sand	4.6
Feather Sound B	2/0	sand	4.1
Fountain Cove	2/0	sand	1.5
Gandy Bridge	6/1	sand	0.9
Placido Bayou	5/2	sand	0.8
Porpoise Point	5/0	sandy loam	2.5
Tiger Point	2/1	loamy sand	3.0
> 5 Years Old			
Bay Shore Parkway	3/0	loamy sand	6.4
Gardinier Chemical	2.5/1	loamy sand	2.5
Natural Marshes			
Bay Point Natural	2/1	sand	3.2
Deaf School	3/1	sand	0.2
Gardinier Natural	3/2	sandy loam	10.4
Philippi Park	4/1	sand	1.6
Power Plant	4/1	sandy loam	7.2
Tiger Point Natural	2/1	sandy loam	14.4

2 m, whereas other sites of similar age had vegetation less than half as tall; the average height of *Spartina* was 102.5 cm (SD = 31.6). Density of *Spartina* was highly variable and ranged from 14.0 stems per 0.25 m^2 on a 2-year-old site to 94.3 stems per 0.25 m^2 on a 4-year-old site (mean = 46.5, SD = 21.7).

The sections of the natural marshes studied averaged 0.49 ha (SD = 0.25 ha). The average cover of *Spartina* was 50.5 percent (SD = 11.8). Three had similar cover of *Spartina* (approximately 55 percent) while one was more sparsely vegetated (33.0 percent cover). Total cover averaged 55.8 percent (SD = 13.7); height of *Spartina* averaged 76.5 cm (SD = 13.2). *Spartina* stem density averaged 37.1 per 0.25 m^2 and was highly variable (SD = 14.3). Table 3 includes vegetation data for all the sites.

Comparisons between the natural marshes and each age class of man-made marshes revealed some unusual differences. For example, total cover on sites less than 1.5 years old was significantly greater than on natural sites (80.5 percent versus 55.8 percent, P = 0.03) and approached significance for the 3-to-5 and greater than 5-year-old age classes (P = 0.13 for both). These differences in cover were largely due to the design and subsequent development of the plant communities on some man-made marshes. The two sites in the youngest age class that were mainly responsible for the significant difference were narrow strips of very dense *Spartina* growing at approximately the same elevation. One of these sites, Canaveral Bay, is shown in Figure 4. Because of their design, these sites lacked areas dominated by *Batis maritima*, *Salicornia* spp., or other high marsh species as well as different height forms of *Spartina*. They also lacked salt pans, tidal creeks, and other physical features that were responsible for the open conditions on portions of some natural marshes (Figure 5). Several sites in other age classes were of similar design and also had a higher percent total cover than natural marshes.

There were also significant differences in the height of *Spartina* among the three youngest age classes and the natural marshes (126.6, 92.5, and 95.1 cm versus 76.5 cm). High levels of nutrients were probably responsible, as several sites with very robust *Spartina* were located at the base of sloping lawns and likely received runoff containing fertilizer. Also, significant height growth on some of the younger sites can likely be attributed to the slow-release fertilizer that is often applied at the time of planting.

These differences in vegetation characteristics were unexpected since it was assumed that the planted vegetation would develop steadily, coalesce after 1 to 2 years, and attain coverage and heights similar to that of natural marshes. Since the youngest sites were approximately 1.5 years old at the time they were sampled, trends in development prior to that age could not be examined. However, subsequent to that, no significant trends could be detected and most r^2 values obtained by regressing vegetation characteristics against age were very low.

Table 3
Vegetation Characteristics of Man-Made and Natural Marshes

Site	Percent Canopy Cover							Density of[1] *Spartina* × (SD)	Height (cm) of *Spartina* × (SD)
	Spartina alterniflora	*Batis maritima*	*Distichlis spicata*	*Juncus roemerianus*	*Paspalum distichum*	Mangrove seedling	Total		
<1.5 Years Old									
Bouchelle Island	74.0	0	0	0	0	0	74.0	52.6 (14.9)	120.6 (35.5)
Canaveral Bay[2]	72.5	0	0	0	0	0	100.0	25.0 (1.4)	188.0 —
Harbor Isles	79.1	0	0	0	0	0	96.7	29.3 (10.8)	180.0 (20.0)
Mariner's Square	48.6	0	0	0	24.3	0	78.6	28.0 (0)	81.8 (10.8)
MacDill AFB	59.5	0	0	0	0	3.5	61.0	62.4 (15.3)	99.1 (24.4)
Thunder Bay	52.0	0	0	0	19.5	0	72.5	45.8 (9.8)	90.1 (26.9)
1.5 - 3 Years Old									
Feather Sound A	55.0	0	0	0	12.5	2.5	65.0	26.8 (4.8)	89.3 (20.0)
Harbour Island	60.0	0	0	0	8.2	0	66.7	42.0 (8.5)	97.6 (26.6)
Ramada Hotel	47.0	0	0	0	0	0	48.0	14.0 (6.0)	117.5 (17.0)
Destin Yacht Club	61.4	0	0	0	0	0	61.4	75.3 (27.6)	104.3 (15.1)
Sea Grove West	40.0	2.1	0	0	2.1	0.5	43.7	73.3 (34.8)	45.9 (20.6)
St. John's Landing	62.9	0	0	0	0	0	62.9	34.3 (3.8)	88.1 (19.2)
Williamson's Home	76.0	0	5.0	0	0	0	82.0	46.2 (16.7)	105.3 (11.3)

1 Number of stems per 0.25-m^2 quadrat.
2 Height estimated· could not be measured due to high winds.

Continued

Table 3 (Concluded)

Site	Percent Canopy Cover							Density of *Spartina* × (SD)	Height (cm) of *Spartina* × (SD)
	Spartina alterniflora	*Batis maritima*	*Distichlis spicata*	*Juncus roemerianus*	*Paspalum distichum*	Mangrove seedling	Total		
3 - 5 Years Old									
Costa del Sol	66.5	2.0	1.0	0	0	0	69.0	78.3 (20.9)	95.1 (26.3)
Feather Sound B	56.0	1.0	0	0	0	2.0	57.0	23.6 (5.0)	83.9 (10.5)
Fountain Cove	51.0	0	19.0	0	12.0	0	86.0	25.0 (13.0)	118.0 (28.0)
Gandy Bridge	50.0	0	0	0	2.0	6.0	60.0	46.5 (10.6)	93.8 (17.6)
Placido Bayou	58.8	2.7	0	0	1.2	3.2	69.4	94.3 (19.9)	103.5 (34.0)
Porpoise Point	64.0	7.1	0	0	0	0	68.9	39.7 (14.6)	76.0 (13.0)
Tiger Point	9.7	0	17.0	30.7	0	0	57.4	38.5 (3.5)	70.9 (9.0)
>5 Years Old									
Bay Shore Parkway[1]	47.5	0	0	0	0	0	76.6	45.3 (3.1)	100.0 --
Gardinier	72.4	0	1.8	0	0	0	73.8	69.8 (30.9)	88.0 (22.2)
Natural Marshes									
Bay Point Natural	0	0	1.0	66.0	0	0	67.0	-- --	-- --
School for Deaf	58.7	0	0	0	0	0	63.2	30.8 (20.2)	65.0 (16.8)
Gardinier Natural	54.5	3.5	0	0	0	0	59.5	49.4 (11.6)	80.7 (21.8)
Phillippi Park	33.0	0	0	0	0	3.0	36.0	16.8 (10.0)	67.0 (16.0)
Power Plant	55.9	6.1	0	0	0	0.8	64.5	44.4 (13.0)	93.2 (21.7)
Tiger Point Natural	3.3	0	0	75.1	0	0	78.4	62.0 (5.7)	74.3 (7.8)

Figure 4. Robust growth of *Spartina* on 1-year-old Canaveral Bay site. Note narrow fringe configuration

Below-ground Biomass

Amounts of below-ground biomass ranged from 3.2 g to 13.2 g and were highly variable (Table 4). Standard deviations were large, some nearly as large as the mean. Development of below-ground biomass was not related to age of the marshes ($r^2 = 0.14$); in fact, several marshes under 5 years old exhibited significant below-ground development (Figure 6). Of the four age classes of man-made marshes, only the 1.5- to 3-year-old sites had significantly lower below-ground biomass than the natural marshes ($P = 0.09$).

Although these data suggest that there is little difference in the below-ground biomass between man-made and natural marshes, the results have to be viewed cautiously. Many factors including nutrient levels (Valiela et al. 1976), elevation (Newling and Landin 1985), and the presence of benthic organisms like fiddler crabs and mussels (Ellison et al. 1986) have been shown to influence below-ground productivity so the variation seen both within and among marshes in this study is not surprising. Comparison with other studies is difficult because of the limited number that have been conducted and the differing techniques used in collecting and reporting data. A more detailed study with larger numbers of samples is necessary to fully evaluate this aspect of the development of man-made marshes.

Birds

Thirty-eight species of birds were found on the man-made wetlands; two additional species occurred on the natural marshes (Table 5). Several such as the least tern (*Sterna antillarum*) and black skimmer (*Rynchops niger*) foraged in open water adjacent to the planted marsh and although they were "on-site," did not actually use the marsh. Many species occurred on only one or a few of the sites; in general, numbers of species and individuals on a given marsh were low. Some birds such as the green-backed heron (*Butorides striatus*) and tri-colored heron (*Egretta tricolor*) were observed on several sites; however, they do not nest in marshes and use a variety of shallow freshwater and intertidal habitats for foraging. Focusing on species that are dependent on marshes for all their needs (such as the seaside sparrow (*Ammodramus maritimus*), clapper rail, or marsh wren) provides the most insight into the success of man-made marshes to mitigate for loss of natural marsh habitat. The remainder of the discussion centers on these "marsh-dependent" species.

Twelve (57.1 percent) of the man-made wetlands supported marsh-dependent birds (Table 6). Marshes in all age classes were used by some of these species; the lowest use was in the youngest age class. Ten of the sites supported at least two marsh-dependent species; three sites supported four marsh-dependent species. The clapper rail was the most common marsh-dependent bird with 26 individuals found. The highest number of

Table 4
Below-Ground Biomass of Man-Made and Natural Marshes

Site	Mean ±(S.D.)[1]	Grams/m^2
< 1.5 Years Old		
Bouchelle Island	13.2 (9.7)	3,429
Canaveral Bay	8.4 (6.1)	2,182
Harbor Isles	6.1 (5.8)	1,584
Mariner's Square	5.7 (2.5)	1,481
MacDill AFB	7.6 (4.3)	1,974
Newman's Residence	— —	—
Thunder Bay	6.5 (2.6)	1,688
1.5 - 3 Years Old		
Destin Yacht Club	3.2 (2.3)	831
Feather Sound A	— —	—
Harbour Island	4.0 (2.1)	1,039
Ramada Hotel	3.5 (2.6)	903
Sea Grove West	5.3 (1.8)	1,377
St. John's Landing	7.0 (3.6)	1,818
Williamson's Residence	7.4 (2.2)	1,922
3 - 5 Years Old		
Costa del Sol	5.5 (2.8)	1,423
Feather Sound B	— —	—
Fountain Cove	8.8 (4.4)	2,286
Gandy Bridge	12.9 (4.7)	3,351
Placido Bayou	8.6 (7.2)	2,234
Porpoise Point	10.1 (5.5)	2,623
Tiger Point	6.7 (4.6)	1,740
> 5 Years Old		
Bay Shore Parkway	9.7 (6.5)	2,519
Gardinier Chemical	9.2 (4.0)	2,390
Natural Marshes		
Bay Point Natural	5.0 (4.1)	1,299
Deaf School	12.3 (4.4)	3,195
Gardinier Natural	6.4 (3.2)	1,662
Philippi Park	4.1 (1.2)	1,065
Power Plant	10.7 (4.4)	2,779
Tiger Point Natural	13.1 (10.1)	3,403

[1] *Dry weight (g) of material in a 7-cm-diam core taken to a depth of 18 cm.*

Figure 6. Root development in 2-year-old man-made marsh

clapper rails on a man-made marsh was eight at the Gardinier site; at least two clapper rails were found on seven marshes.

Nests of marsh-dependent birds were found only on two man-made sites—two marsh wren nests at Thunder Bay, a young marsh, and four clapper rail nests at Gardinier, the second-oldest marsh. In addition, a very young clapper rail chick was found at Thunder Bay and a half-grown clapper rail chick at Gardinier. Presumably both hatched on the sites. Only one clapper rail nest was found in a natural marsh (School for the Deaf). Since intensive nest searches were not conducted, it is not possible to draw conclusions regarding the overall value of man-made marshes as nesting habitat. However, it was apparent that some man-made wetlands, even young ones, are suitable for nesting.

Vegetation density is probably one of the main factors influencing site use by many marsh-dwellers. A number of the common marsh residents are secretive and require the presence of at least moderate cover. For example, Gutzwiller and Anderson (1987) stated that 50 percent is the minimum cover acceptable to the marsh wren; 63.0 percent is moderately good, and 80 to 100 percent is optimum. The clapper rail is somewhat more tolerant of sparse vegetation although optimum cover is between 50 and 100 percent (Lewis and Garrison 1983).

Table 5
Species of Birds Found in Man-Made and Natural Marshes

Common Name	Scientific Name	Man-Made	Natural
Anhinga	*Anhinga anhinga*	X	
Least bittern	*Ixobrychus exilis*		X
Great blue heron	*Ardea herodias*	X	
Great egret	*Casmerodius albus*	X	
Snowy egret	*Egretta thula*	X	X
Tricolored heron	*Egretta tricolor*	X	X
Cattle egret	*Bubulcus ibis*	X	X
Green-backed heron	*Butorides striatus*	X	X
Yellow-crowned night heron	*Nycticorax violaceus*	X	
White ibis	*Eudocimus albus*	X	X
Roseate spoonbill	*Ajaia ajaja*	X	
Wood stork	*Mycteria americana*	X	
Mottled duck	*Anas fulvigula*	X	
Black rail	*Laterallus jamaicensis*	X	
Clapper rail	*Rallus longirostris*	X	X
King rail	*Rallus elegans*	X	
Virginia rail	*Rallus limicola*	X	X
Sora	*Porzana carolina*	X	X
Common moorhen	*Gallinula chloropus*	X	
American coot	*Fulica americana*	X	
Black-bellied plover	*Pluvialis squatarola*	X	
Semipalmated plover	*Charadrius semipalmatus*	X	X
Killdeer	*Charadrius vociferus*	X	
Greater yellowlegs	*Tringa melanoleuca*	X	X
Lesser yellowlegs	*Tringa flavipes*	X	
Willet	*Catoptrophorus semipalmatus*	X	X
Spotted sandpiper	*Actitis macularia*	X	
Least tern	*Sterna antillarum*	X	
Black skimmer	*Rynchops niger*	X	

Continued

Table 5 (Concluded)			
Common Name	**Scientific Name**	**Man-Made**	**Natural**
Mourning dove	*Zenaida macroura*	X	
Eastern kingbird	*Tyrannus tyrannus*		X
Barn swallow	*Hyrundo rustica*	X	
Marsh wren	*Cistothorus palustris*	X	X
Common yellowthroat	*Geothlypis trichas*	X	X
Northern cardinal	*Cardinalis cardinalis*	X	
Rufous-sided towhee	*Pipilo erythrophthalmus*	X	X
LeConte's or sharp-tailed sparrow	*Ammodramus* spp.	X	X
Seaside sparrow	*Ammodramus maritimus*	X	X
Red-winged blackbird	*Agelaius phoeniceus*	X	X
Boat-tailed grackle	*Quiscalus major*	X	

The results of this study agree with the above information. Of the ten man-made wetlands in which clapper rails were found, only two had *Spartina* cover of less than 50 percent (47.0 and 47.5 percent); the average cover was 57.2 percent. One marsh used by clapper rails with less than 50-percent *Spartina* cover was Bay Shore Parkway. It had *Scirpus robustus* growing as a codominant so the effective (total) cover was 76.6 percent. Bay Shore Parkway was also the only site with less than 50 percent *Spartina* cover that was used by marsh wrens. That species was found on seven sites, with an average *Spartina* cover of 56.0 percent. Figure 7 shows a man-made marsh with a cover density suitable for these species while Figure 8 shows a marsh on which the cover density is unacceptably sparse.

Configuration of man-made wetlands may be an important influence on use by some birds. Narrow fringes of *Spartina* were seldom used by marsh-dependent birds; of 10 man-made marshes with this configuration, only two supported marsh-dependent birds. Of the two fringe marshes that were used by marsh-dependent birds, one (Bay Shore Parkway) was relatively wide (average width approximately 7 m) and apparently provided acceptable habitat. Marsh-dependent species found there included one clapper rail, four sora rails (*Porzana carolina*), and one marsh wren. The other, Costa del Sol, was used by only one marsh-dependent bird; a king rail (*Rallus elegans*). The unfavorable configuration coupled with the proximity to developed areas (Figure 9) appears to be responsible for the low use of several marshes in the youngest age class. Four of the young sites were fringes, and three of the four were adjacent to developed areas.

Table 6
Marsh-Dependent Birds Found in Man-Made and Natural Marshes

Site	*Ammodramus maritimus*	*Cistothorus palustris*	*Laterallus jamaicensis*	*Porzana carolina*	*Rallus elegans*	*Rallus limicola*	*Rallus longirostris*
<1.5 Years Old							
Bouchelle Island	0	0	0	0	0	0	0
Canaveral Bay	0	0	0	0	0	0	0
Harbor Isles	0	0	0	0	0	0	0
Mariner's Square	0	0	0	0	0	0	0
MacDill AFB	2	0	0	0	0	0	1
Thunder Bay	0	1	0	0	0	0	3
1.5 - 3 Years Old							
Feather Sound A	0	2	0	0	0	0	2
Harbour Island	1	1	0	0	1	0	1
Ramada Hotel	0	0	0	0	0	0	3
Destin Yacht Club	0	0	0	0	0	0	0
Sea Grove West	0	0	0	0	0	0	0
St. John's Landing	0	1	0	0	0	1	0
Williamson's Home	0	0	0	0	0	0	0
3 - 5 Years Old							
Costa del Sol	0	0	0	0	1	0	0
Feather Sound B	3	3	0	2	0	0	2

Continued

Table 6 (Concluded)

Site	*Ammodramus maritimus*	*Cistothorus palustris*	*Laterallus jamaicensis*	*Porzana carolina*	*Rallus elegans*	*Rallus limicola*	*Rallus longirostris*
3 - 5 Years Old (Concluded)							
Fountain Cove	0	0	0	0	0	0	0
Gandy Bridge	0	0	0	0	0	0	0
Placido Bayou	0	2	1	2	0	0	3
Porpoise Point	1	0	0	0	0	0	2
Tiger Point	0	0	0	1	0	2	2
>5 Years Old							
Bay Shore Parkway	0	1	0	4	0	0	1
Gardinier	0	0	0	4	0	0	8
Natural Marshes							
Bay Point Natural	0	0	0	1	0	0	8
Gardinier Natural	0	0	0	0	0	0	4
Phillippi Park							
Power Plant	0	0	0	0	0	0	2
School for Deaf	1	1	0	1	0	2	9
Tiger Point Natural	0	0	0	3	0	1	3

Figure 7. Man-made marsh that provided suitable cover for marsh-dependent birds

Figure 8. Man-made marsh with sparse vegetation cover that is unsuitable for marsh-dependent birds

Figure 9. Man-made marsh with narrow fringe configuration. (This condition, coupled with proximity to developed areas, severely reduced habitat value for marsh-dependent birds.)

Wetland size is another factor related to use by some species and may explain why some marshes were not used by marsh-dependent birds. Lewis and Garrison (1983) stated that 2 ha was the minimum area needed to support clapper rails and Gutzwiller and Anderson (1987) noted that 0.4 ha is usually necessary to provide habitat for marsh wrens. Both species were found on areas smaller than the above minimums, but it is still noteworthy that optimum conditions for some marsh-dwelling birds require the presence of relatively large areas.

Mammals

Raccoons (*Procyon lotor*) and marsh rabbits (*Sylvilagus palustris*) were the only larger mammals found on any of the sites (Table 7). One raccoon was observed on each of two man-made marshes, while tracks were found on five others and on one natural marsh. Marsh rabbits were observed on three man-made marshes while pellets were found on two others and on one natural marsh.

Table 7
Mammals Found in Man-Made and Natural Marshes

Site	Species Captured					Observed or Found Sign	
	Oryzomys palustris	*Sigmodon hispidus*	Other[1]	Capture[2] Ratio	Number Trap Nights	*Procyon lotor*	*Sylvilagus* spp
<1.5 Years Old							
Bouchelle Island	2	4	0	6.7:20	18	-	-
Canaveral Bay	0	0	0	0	0	x	-
Harbor Isles	0	0	0	0	18	-	-
Mariner's Square	0	0	1	0	20	-	-
MacDill AFB	0	1	0	1:20	20	x	-
Thunder Bay	0	1	0	1.3:20	16	-	-
1.5 - 3 Years Old							
Feather Sound A	8	1	0	14.3:20	13	x	-
Harbour Island	0	0	0	0	20	x	x
Ramada Hotel	0	0	0	0	20	-	x
Destin Yacht Club	0	0	0	0	20	-	-
Sea Grove West	0	2	0	2:20	20	x	-
St. John's Landing	0	0	1	0	23	-	-
Williamson's Home	0	0	0	0	10	-	-

1 *Rattus rattus*, *R. norvegicus*, or *Mus musculus*.
2 Calculated only on *Oryzomys* or *Sigmodon* captures.

Continued

Table 7 (Concluded)

Site	Species Captured			Capture Ratio	Number Trap Nights	Observed or Found Sign	
	Oryzomys palustris	*Sigmodon hispidus*	Other			*Procyon lotor*	*Sylvilagus* spp.
3 - 5 Years Old							
Costa del Sol	0	0	1	0	16	x	x
Feather Sound B	4	3	0	8.7:20	16	-	-
Fountain Cove	0	0	0	0	16	-	-
Gandy Bridge	0	1	0	3.3:20	6	-	x
Placido Bayou	0	0	0	0	16	x	x
Porpoise Point	0	3	0	1.5:20	39	-	-
Tiger Point	0	0	0	0	24	x	-
>5 Years Old							
Bay Shore Parkway	0	0	8	0	20	-	-
Gardinier	6	0	3	6.7:20	18	-	-
Natural Marshes							
Bay Point Natural	0	2	0	2:20	20	x	-
Gardinier Natural	7	3	0	14.3:20	14	-	-
Philippi Park	0	0	0	0	20	x	x
Power Plant	0	0	0	0	20	-	-
School for Deaf	0	0	0	0	20	-	-
Tiger Point Natural	0	1	0	1.2:20	24	-	-

The information on large mammals is scanty. These species are secretive and difficult to observe directly. Further, tracks and scats were difficult to find in densely vegetated marshes and the ability to see either varied greatly with substrate color and texture, and time since inundation. A more intensive study involving trapping would be needed to identify habitat factors that influence use of man-made marshes by these species.

The only two native small mammals captured on either the man-made or natural marshes were the cotton rat (*Sigmodon hispidus*) and rice rat (*Oryzomys palustris*). The Norway rat (*Rattus norvegicus*) and black rat (*R. rattus*), were present on one site each and the house mouse (*Mus musculus*) occurred on three sites. Numbers of animals captured by site are listed in Table 7. The unequal number of trap-nights was due to variation in size of the marshes and to losses of traps and/or bait to raccoons. The remainder of the discussion on small mammals deals only with the native species.

Native small mammals were captured on nine man-made marshes and on one natural marsh. The highest capture ratio was 14.3 animals per 20 trap-nights at both Feather Sound A and Gardinier Natural. Numerous captures were made on three other man-made marshes. One site in each age class had a capture ratio of at least 6.7:20. Although it is reasonable to assume that sites on which several animals were captured supported a high small mammal population, the data have to be viewed cautiously because of the brief period during which trapping was conducted. Determining density estimates requires an intensive effort and was beyond the scope of this study. Reasons for lack of captures in natural marshes are not known but may be attributed to the abbreviated sampling period. Two of the sites appeared to be excellent habitat, as did four man-made marshes in which no captures were made. Enough data were gathered, however, to allow some inferences regarding man-made marshes and small mammals.

Total cover of marshes used by small mammals ranged from 43.7 to 74.0 percent and averaged 64.0 percent (SD = 9.9). Plant cover in the four marshes with the largest number of captures was moderate to dense (range = 57.0 to 74.0, mean = 67.5, SD = 8.1). Total cover on the natural marsh in which small mammals were captured was 59.5 percent. All five sites with high capture ratios had a zone of high marsh vegetation (generally *Distichlis spicata* or *Paspalum distichum*) surrounding the *Spartina* zone (Figure 10). The high marsh zone may influence the use of sites by providing a refuge during normal daily inundation. Dense vegetation that is not flooded is probably more valuable to the cotton rat than to the rice rat, as the former is a more terrestrial species and prefers the marsh-upland interface (Stout 1984). However, the presence of a high-marsh zone did not seem to be critical in determining site use; six of the 11 man-made marshes where no captures were made had a densely vegetated fringe.

Small mammals are probably influenced more by vegetation structure and a nearby source of colonists than by site age. Even very young sites

Figure 10. Man-made marsh with high population of small mammals. (Note cover above the *Spartina* zone.)

were capable of providing an acceptable habitat; for example, three marshes in the youngest age class supported small mammals. All were similar in that they had more than 50 percent cover in the *Spartina* zone, a dense fringe of high marsh vegetation, and were adjacent to natural wetlands so colonization of the new wetlands could have taken place rapidly. As with marsh-dependent birds, configuration of man-made wetlands may exert an influence on use by small mammals. Seven of nine sites on which small mammals were captured were of a block configuration.

Fish

A total of 31 species of fish were collected from the sites during the study; 21 from the Gulf coast and 24 from the Atlantic coast. Three additional species were found only in *Juncus*-dominated marshes on the Gulf coast. Common species included the Gulf killifish (*Fundulus grandis*), long-nose killifish (*F. similis*), diamond killifish (*Adenia xenica*), rainwater killifish (*Lucania parva*), sheepshead minnow (*Cyprinodon variegatus*), mosquitofish (*Gambusia affinis*), sailfin molly (*Poecilia latipina*), spot mojarra (*Eucinostomus argenteus*), and darter goby (*Gobionellus boleosomo*).

One of the best indicators of the value of man-made marshes as fish habitat is the extent to which they are used by common marsh residents. Numbers of several common species, total number of individuals collected, and equitability and similarity indices are listed in Tables 8 and 9. Gulf and Atlantic Coast marshes are discussed separately because geographic variation exists in fish communities. Two natural *Spartina* marshes were sampled on the Gulf Coast, but only the Gardinier Natural site was used in the comparison of fish communities. The Phillippi Park site was considerably different from the man-made wetlands and from the Gardinier Natural site because it was directly on a major water body (Tampa Bay) instead of being in a cove, inlet, or other protected location. It was also sparsely vegetated and was located in an area where water quality is generally poor (Kunneke and Palik 1984).

There was some variation among the Gulf Coast man-made marshes and between them and the Gardinier Natural marsh. However, the differences were not great and all but one of the man-made marshes supported at least five of the eight common species listed in Table 8. Similarity indices (between each man-made marsh and the natural marsh) ranged from [illegible] to 0.82; only two of nine were lower than 0.50, the point at which sites have 50 percent of their species in common. Regression of C_s with age indicated that fish use of man-made marshes was not related to age ($r^2 = 0.003$). Interestingly, Thunder Bay, a site in the youngest age class, was most similar to the natural site ($C_s = 0.82$).

There was more among-site variability in Atlantic Coast fish communities than in the Gulf marshes. Six of the man-made marshes and both natural marshes supported at least four of the common species in Table 9. Based on proximity, the Porpoise Point marsh was compared to the School for the Deaf marsh; the others to the Power Plant marsh. C_s for the Porpoise Point School for the Deaf comparison is 0.63; most of the other comparisons (with the Power Plant marsh) are somewhat poorer, although six are above 0.50 (range = 0.29 to 0.67.). There was no significant relationship between C_s and age ($r^2 = 0.11$) for the sites compared to the Power Plant marsh.

Factors that exerted a strong influence on use of man-made marshes by fish could not be identified. Correlations of age, size, and total vegetation cover of marshes with the total numbers of fish captured on each site were all extremely poor (r = 0.10, 0.06, and 0.03, respectively). The lack of good correlations was not unexpected, as even natural marshes were variable in species composition and numbers. Besides onsite conditions such as vegetation cover, the location of the marsh and nearby habitat conditions probably influenced site use. In addition, sampling procedures may have caused some of the variability. Species differentially use portions of a marsh; for example some are normally associated with tidal creeks or permanent pools while others are transients. Since each of these habitats could not be sampled separately, it is possible that some species were missed or under-represented.

Table 8
Common Fish Collected from Man-Made and Natural Marshes on the Gulf Coast

Site (C_s)[1]	*Adenia xenica*	*Cyprinodon variegatus*	*Fundulus confluentus*	*Fundulus grandis*	*Fundulus similis*	*Gambusia affinis*	*Lucania parva*	*Poecilia latipinna*	Total[2]
<1.5 Years Old									
MacDill AFB (0.67)	21	20	0	7	20	0	2	25	145
Thunder Bay (0.82)	165	57	1	17	16	1	1	3	261
1.5 - 3 Years Old									
Feather Sound A (-)	-	-	-	-	-	-	-	-	--
Harbour Island (0.67)	3	128	0	53	80	1	0	21	490
Ramada Hotel (0.46)	33	71	0	310	181	0	31	365	1,954
Destin Yacht Club (0.33)	0	1	0	1	0	0	0	0	8
3 - 5 Years Old									
Feather Sound B (-)	-	-	-	-	-	-	-	-	--
Gandy Bridge (0.53)	9	88	0	21	19	0	0	93	248
Placido Bayou (0.71)	48	4	20	7	0	0	0	11	90
Tiger Point (0.48)	7	5	16	0	16	0	0	10	68
>5 Years Old									
Bay Shore Parkway (0.53)	0	4	0	12	0	30	16	182	253
Gardinier (0.75)	700	148	162	34	0	27	1	2	1,074
Natural Marshes									
Bay Point Natural (0.78)	3	22	9	4	1	7	30	45	123
Gardinier Natural (-)	232	15	60	41	1	17	0	12	380
Philippi Park (0.33)	0	26	0	15	4	0	11	0	413
Tiger Point Natural (0.67)	16	15	6	17	13	0	0	14	104

1 Similarity index.
2 Number of individuals of all species.

Table 9
Common Fish Collected from Man-Made and Natural Marshes on the Atlantic Coast

Site (C_s)[1]	*Cyprinodon variegatus*	*Eucinostomus argenteus*	*Fundulus grandis*	*Gambusia affinis*	*Gobionellus boleosomo*	*Lucania parva*	*Poecilia latipinna*	Total[2]
<1.5 Years Old								
Bouchelle Island (0.67)	0	7	6	7	3	0	31	50
Canaveral Bay (0.38)	24	0	18	456	0	132	279	927
Harbor Isles (0.29)	92	0	0	349	0	137	237	823
Mariner's Square (0.50)	1	0	3	0	0	0	3	7
1.5 - 3 Years Old								
Sea Grove West (0.53)	0	1	2	0	0	0	1	9
St. John's Landing (-)	-	-	-	-	-	-	-	-
Williamson's Home (0.36)	0	0	7	0	0	0	0	8
3 - 5 Years Old								
Costa del Sol (0.50)	185	1	11	10	0	571	39	818
Fountain Cove (0.56)	126	1	7	69	0	230	192	638
Porpoise Point (0.63)	0	82	52	0	11	0	1	172
Natural Marshes								
Power Plant (0.63)	7	10	32	0	20	0	1	79
School for Deaf (0.63)	0	23	65	0	6	0	36	149

1 Similarity index.
2 Number of individuals of all species.

Three sites from which significantly fewer fish were collected provide some insight regarding factors that affect the value of man-made marshes as habitat for fish. The three, Destin Yacht Club (Figure 11), Mariner's Square, and Williamson's Residence were small, narrow, fringe marshes located in areas where few wetlands remained. The scarcity of marsh dwellers in the vicinity may alone have been responsible for the low numbers; however, design of the sites was probably also a contributing factor. These and most other fringe marshes lacked the habitat complexity (i.e., tidal creeks, permanent pools, high marsh vegetation) of natural marshes. The absence of these features limits foraging and cover options for fish. Narrow fringe marshes also lacked an elevational gradient which resulted in their being inundated and dewatered rapidly. Under these conditions, small forage fish do not have the opportunity to seek alternative cover as the tide ebbs. Narrow fringes also concentrate fish, thereby increasing their susceptibility to predation. Some of the narrow fringe marshes did have other zones of vegetation present and were like marsh ecosystems in miniature. The value of this design is questionable, however, as zones were often no more than 0.75 to 1 m wide so the amount of cover they provided for fish (or other animals) was minimal.

Although narrow fringe marshes have characteristics which possibly reduce their value as fish habitat, some were heavily used. The total number of fish taken from both the Canaveral Bay and Harbor Isles sites was

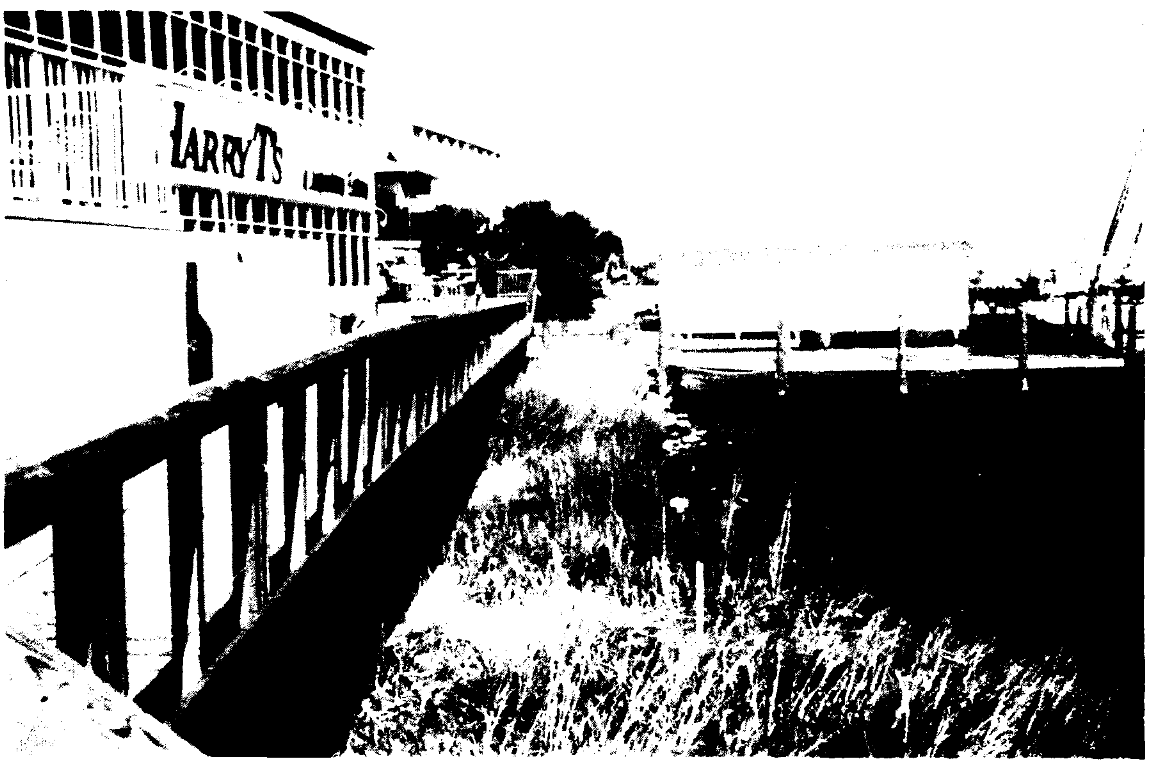

Figure 11. Narrow, fringe marsh in an area with extensive development. (Sites like these provided marginal habitat quality for fish.)

very high; in fact, more than twice as many fish were captured on them as on any of the natural marshes.

Surface Macroinvertebrates

Four genera of macroinvertebrates were found on the study sites (only the marsh periwinkle (*Littorina irrorata*) was identified to species) (Table 10). Although there was site-to-site variation, several of the man-made marshes supported the same organisms as the natural marshes. At least one of these genera was found on over one half of the man-made marshes and all but one of the natural marshes; several man-made marshes were used by at least two of the genera.

Marshes in all age classes supported some macroinvertebrates and even very young marshes are capable of providing favorable habitat. For example, both MacDill Air Force Base and Thunder Bay supported notably large numbers of macroinvertebrates. Fiddler crabs (*Uca* spp.) were common on some sites (Thunder Bay and Sea Grove West are two with large *Uca* populations) but no quantitative data were gathered on them. Although the counts within the quadrats do provide some measure of comparison, these organisms are not randomly distributed in marsh systems and may have been missed during the sample. Their absence from Table 10 does not mean they were not present on the site.

Table 10
Macroinvertebrates Occurring in Marshes

Site	*Cerithidae* spp.[1]	*Geukensia* spp.[1]	*Littorina* spp.[1]	*Melampus* spp.[1]
<1.5 Years Old				
Bouchelle Island	0	0	0	0
Canaveral Bay	0	0	0	0
Harbor Isles	0	0	0	0
Mariner's Square	0	0	0	0
MacDill AFB	4.4	1.2	15.0	0
Newman's Residence	0	0	0	0
Thunder Bay	38.0	0	1.5	2.0
1.5 - 3 Years Old				
Destin Yacht Club	0	0	0	0
Feather Sound A	0	0	0.3	0
Harbour Island	0	0	1.3	0
Ramada Hotel	0	0	13.0	0
Sea Grove West	0	0	0	0
St. John's Landing	0	0	15.3	0
Williamson's Residence	0	0	0	0

[1] Number per 0.25 m^2.

Continued

Table 10 (Concluded)

Site	*Cerithidae* spp.	*Geukensia* spp.	*Littorina* spp.	*Melampus* spp.
		3 - 5 Years Old		
Costa del Sol	0	0	0	0
Feather Sound B	12.5	0	4.8	1.0
Fountain Cove	0	0	0	0
Gandy Bridge	0	0	2.8	0.8
Placido Bayou	9.5	4.5	0	0
Porpoise Point	0	0	0	0
Tiger Point	0	0	1.5	0
		> 5 Years Old		
Bay Shore Parkway	0	0	20.5	0
Gardinier Chemical	5.4	4.2	0.2	1.4
		Marshes		
Bay Point Natural	0	0.8	8.8	0
Deaf School	0	0	5.0	0
Gardinier Natural	7.6	14.0	10.4	0.6
Philippi Park	0	43.0	10.0	0
Power Plant	0	0	0	0
Tiger Point Natural	0	0.8	9.8	0

4 Conclusions

Most man-made *Spartina* marshes in northern and central Florida were utilized by species of fish and wildlife commonly associated with naturally occurring marshes. Although there was variability among sites, marshes of all ages were used by marsh-dependent birds, small mammals, and fish. If properly planned, constructed, and maintained, man-made *Spartina* marshes have fish and wildlife habitat value similar to naturally occurring marshes.

More attention should be paid to the location of man-made wetlands. Situating wetlands in heavily developed areas can adversely impact their success. In addition to reduced habitat value, there is an increased probability that a project will be short-lived. For example, one marsh used in the study had been cut down 2 years after it was planted by the developer who mistakenly thought dormant *Spartina* was dead. Portions of it continue to be cut (Figure 12). Two other marshes in the study were subsequently destroyed as developers constructed new condominiums on their properties (Figures 13 and 14). Improper location was also found to sometimes result in purposeful destruction; one man-made marsh visited in 1986 had (apparently) been sprayed with herbicide because the *Spartina* grew through and over the adjacent boat dock. Another marsh, adjacent to a city park, was being regularly mowed along with the lawn when visited in 1989 (Figure 15).

Although the technology to create wetlands is sound, results are sometimes not as good as they should be. Several of the sites visited had been improperly constructed, causing them to fail outright. Incorrect elevation (Figure 16) and erosion due to wave action (Figure 17) were the most common problems. Even with "successful" projects, designers often failed to consider the habitat requirements of species found in coastal marshes. Some marshes were so small that they did not meet the minimum area necessary to provide habitat for common marsh-dwelling birds. If fish or wildlife habitat is the intended function of a man-made marsh, planners should avoid constructing small, narrow, fringe marshes and construct block-shaped ones at least 0.5 ha in size (Figure 18). Combining several small projects should be considered, especially if off-site mitigation is an option.

Figure 12. Portion of the Fountain Cove Marsh cut down by maintenance crew

Figure 13. Costa del Sol Marsh as it appeared during the study

Figure 14. Costa del Sol Marsh after construction of new apartments

Figure 15. Melbourne Harbor Marsh (not included in study) after being mowed along with the adjacent city park

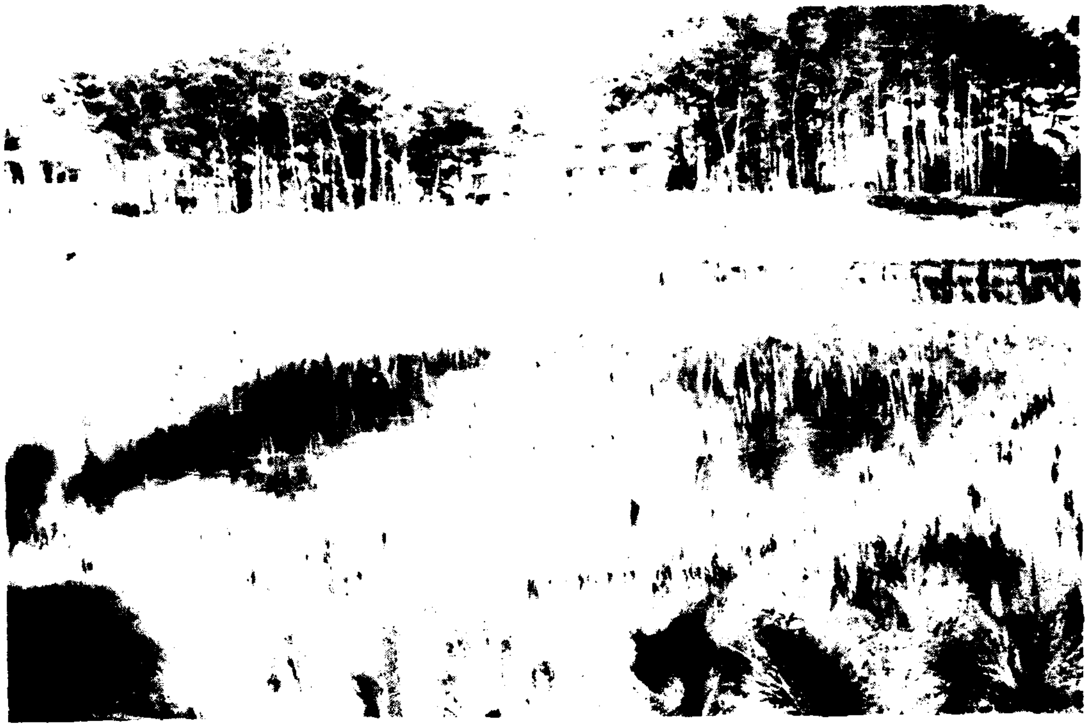

Figure 16. Bay Point Marsh flooded at low tide due to incorrect elevation and/or a poorly designed tidal connection

Figure 17. Mariner's Square Marsh showing severe wave erosion

Figure 18. Portion of Feather Sound Marsh with well-developed *Spartina*. (Note diversity created by tidal creek and shallow intertidal flat.)

In a study such as this, it was not possible to gather comprehensive data on any marsh. However, a major benefit of the design was that a relatively large number of sites were studied. This allowed identification of both good and bad design features. While questions regarding man-made wetlands still remain, this study provided considerable insight into their value as habitat for fish and wildlife. By carefully incorporating species habitat requirements into project design and locating wetlands where their habitat value can be realized, planners can improve the ability of man-made wetlands to replace the habitat value of wetlands destroyed by unavoidable development.

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